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Issued May 1929
Slightly revised May 1946

LEAFLET No. 34
U.S. DEPARTMENT OF AGRICULTURE

TRICHINOSIS

A DISEASE CAUSED BY EATING RAW PORK

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Occurrence and Propagation of the Disease

Trichinosis is a parasitic disease caused by small roundworms bearing the scientific name *Trichinella spiralis,* and commonly known as trichinae. These parasites occur most commonly in human beings, hogs, cats, rats, and dogs. They are reported also from many other warm-blooded animals and may be reared experimentally in almost any mammal. Trichinae will develop in the intestines of birds, but the larvae do not ordinarily become encysted in the muscles of these animals, as they do in those of mammals. So far as is known at the present time, cold-blooded vertebrates, such as fishes, amphibians, and reptiles, are resistant to trichinae.

Concerning trichinosis in man, the only hosts that generally need to be considered are hogs and rats. Ordinarily, human beings acquire trichinosis solely as a result of eating infected, imperfectly cooked pork or products containing muscle tissue of swine. Hogs usually acquire the disease as a result of eating the carcasses of other hogs, offal from slaughterhouses, garbage containing scraps of pork, or infected rats. Rats become infected with trichinae as a result of devouring other rats harboring the encysted stage of the parasite or as a result of eating the carcasses of infected dogs, cats, or other animals, or scraps of infected pork or offal. Country slaughterhouses where rats abound and where hogs are kept and fed offal from slaughtered hogs are probably in no small measure responsible for the propagation of trichinosis. Feeding uncooked garbage to hogs is largely responsible for the propagation of trichinae.

Though trichinosis is serious when it occurs, it is readily preventable, and there is no danger whatever when pork is thoroughly cooked or made safe by other methods to be discussed later. The practical precautions to be observed in the use of pork, which is one of the most appetizing and nourishing foods in the human diet, are readily followed and easily remembered. The need, however, for the main admonition "Cook pork thoroughly" will be understood better from a description and the life history of the parasite.

The parasite (*Trichinella spiralis*) occurs as a sexually mature worm in the small intestine. In its immature stages as a young larval worm it occurs in the lymph, the blood stream, the muscles, and in other locations in the body. It occurs in the infective stage as an encysted larva in the voluntary muscles. Recent investigations conducted in this Bureau showed that trichina larvae occur in small numbers, also, in the heart, liver, and stomach wall of experimentally infected animals.

The sexually mature worms are small and slender, and the females may be rather deeply embedded in the membrane lining the intestine. The male (fig. 1) is about 1.5 millimeters long (about one-sixteenth of an inch) and the female (fig. 2) is from 3 to 4 millimeters long (about one-eighth to one-sixth of an inch). The two sexes differ considerably in their internal structure, but aside from these differences and that of size they may be readily distinguished by the presence on the male tail of a pair of conical protuberances which are lacking in the female.

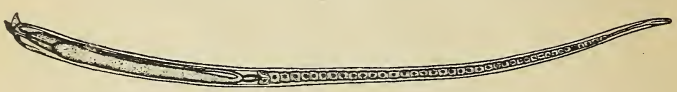


FIGURE 1.— *Trichinella spiralis;* adult male. Enlarged (after Leuckart).

Life History

Intestinal trichinae are acquired by human beings through swallowing the muscle tissue of pork that harbors the encysted stage of the parasite (fig. 4). The encysted worms are freed from their cysts, or capsules, in the human stomach as a result of the digestion of the cyst wall by the gastric juice. Once free in the stomach, the worms pass rapidly into the small intestine, where they settle and molt, increasing in size and becoming sexually mature after molting. The worms become mature males and females 2 to 3 days after the infected meat is eaten. Mating occurs between the sexes, after which the female worms attain their full growth and penetrate more or less deeply into the intestinal lining. Although adult trichinae of both sexes may persist in the intestine for many weeks, these intestinal worms are essentially short-lived and commonly pass out of the intestine soon after their reproductive functions have been fulfilled.

The fertilized eggs develop and hatch within the female and leave the mother worm as free embryos (fig. 2). The birth of this new generation begins within 4 to 5 days after the mating of the adult worms, or from 6 to 7 days after the trichinous meat is eaten. The production of young continues for several weeks, but many more young worms are born during the first 2 weeks than subsequently.

The young worms escape from the female and ordinarily enter directly into the lymph spaces. At this stage the young worm is very minute, being about 100μ long by 6μ wide (about one two-hundred-and-fiftieth by one four-thousandth of an inch). Newly born worms may also be found in the intestine, but in such cases it is very doubtful that they succeed in getting into the circulation and thus reach the muscles. The newly born larvae which pass from the intestinal wall with the lymph reach the thoracic duct, pass into the venous system and thus arrive at the heart, from which organ they are carried into the arterial system. The larval worms are most abundant in the circulating blood from the eighth to the twenty-fifth day after

infection. These larvae are carried by the blood to the various parts of the body, including the voluntary muscles, and in these muscles they leave the capillaries and penetrate the primary muscle bundles. While all voluntary muscles are subject to infection with trichinae, the muscles which as a rule are most heavily parasitized are the most active ones and those with the richest blood supply, such as the diaphragm, intercostal, and laryngeal muscles, and the tongue and eye muscles. The muscles are most heavily invaded by trichina larvae during the ninth and tenth days after infection.

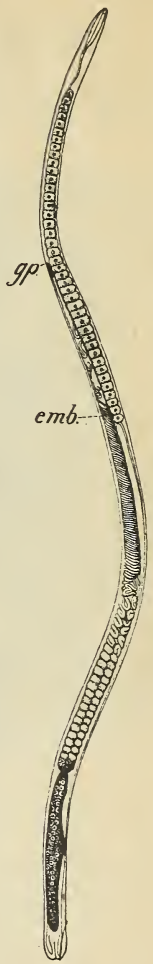


FIGURE 2.—*Trichinella spiralis;* adult female showing embryos, *emb,* in uterus; *gp,* genital opening through which the embryos are discharged. Enlarged (after Leuckart).

Once having penetrated a muscle fiber, the larva increases first in width and later in total width and length. Within 10 days to 2 weeks it reaches a length of about 1 millimeter (one twenty-fifth of an inch), which is about 10 times its original size. It then becomes spirally rolled (fig. 3). Meanwhile the muscle fibers that have been invaded by the larvae and also the neighboring fibers undergo profound degenerative changes, and each parasite becomes surrounded by a membranous cyst formed from intermuscular connective tissue. The cyst (fig. 4), which is about one-fiftieth of an inch in diameter, may be spherical or lemon shaped, the lemon shape being characteristic of trichina cysts in man and the hog, whereas the spherical shape is commonly observed in rats. Although the capsule begins to form within a month after infection it is not completed before the seventh to the ninth week after the eating of trichinous meat. The capsule begins to calcify not earlier than 6 months after infection, and the process of calcification requires at least 12 additional months. However, the parasites may remain alive in the calcified capsule for a long time, even for a period of several years, although sooner or later they die and are absorbed or become calcified, and break down into crumbled masses.

Summary of Life History

The essential phases in the life history of trichinae, which are intimately related to the various manifestations of the disease known as trichinosis, are briefly as follows: When infection occurs as a result of the ingestion of trichinous meat by a human being, the encapsulated larvae become freed in the stomach and migrate to the small intestine, where they undergo several successive molts and emerge as sexually mature worms within 2 to 3 days. Following copulation, the females penetrate deeply into the membrane that lines the intestine, and the young worms which develop within them escape within 4 or 5 days after infection.

The production of young worms continues actively for a period of about 2 weeks, after which the birth rate gradually slows down. The young worms reach the blood stream by way of the lymph channels and are distributed by the arterial circulation to all parts of the body.

They penetrate various organs and spaces in the body but achieve their full growth, as a rule, in voluntary muscles. In these muscles they finally become spirally rolled and enclosed in connective-tissue capsules. If the infected subject remains alive, the capsule undergoes a gradual calcification in the course of time, and sooner or later the parasites die and degenerate or else undergo a similar calcification process.

The Course of the Disease Produced by Trichinae

The course and gravity of the disease, trichinosis, are dependent on the number of encysted larvae that are taken into the body. Slightly infested pork when eaten raw or imperfectly cooked will produce a mild form of the disease, unless large quantities of such lightly infested pork are consumed, whereas the consumption of a small quantity of heavily infested pork may suffice to produce an acute attack of trichinosis.

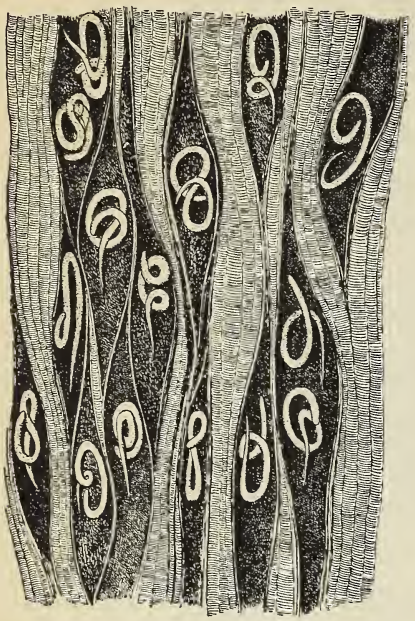


FIGURE 3.— Larvae of *Trichinella spiralis* in a muscle, not yet encysted. Enlarged (after Leuckart).

In severe cases of trichinosis three stages of the disease may be distinguished, as a rule, these stages corresponding to the behavior of the parasites within the body. The first stage, known as the stage of ingression, lasts for about a week and corresponds to the development of the parasites in the intestine and the production of their brood of larvae. It is marked chiefly by gastrointestinal symptoms, which may appear within a few hours following the eating of pork containing live trichinae or may be delayed for a day or longer. There may be nausea, vomiting, diarrhea, and severe abdominal pains, or these symptoms may be entirely lacking. There is usually a general dullness, with a feeling of weakness, twitching of the muscles, and sensations of tension and pain in the muscles, especially the flexors of the limbs. Toward the close of this period, edema (a watery swelling) of the face and eyelids appears and is likely to disappear temporarily, reappearing a few weeks later.

The second stage, which corresponds to the distribution of the larvae to the muscles by the general circulation, is known as the stage of digression. The symptoms appear within 9 to 10 days after trichinous meat is eaten but may be delayed for several days, though usually they appear within 2 weeks at the latest. Severe muscular pains, especially of the flexors, are manifest, and the muscles become tense, hard, and swollen. The eyeball becomes inflamed or may show small hemorrhages. There is difficulty in chewing and swallowing as a result of the invasion by the larvae of the muscles involved in

these processes. There are more or less severe respiratory difficulties owing to the invasion of the intercostal muscles in the chest wall by the larval parasites, and these disturbances become aggravated during the fourth and fifth weeks after the ingestion of trichinous meat, resulting in dyspnoea and asthmatic attacks. Profuse sweating is very common during this stage and may last throughout the course of the disease.

The third period, known as the stage of regression, corresponds to the period of encystment of the parasites and begins about 6 weeks after ingestion of trichinous meat. The symptoms of the second stage become more pronounced, and new symptoms appear. The legs, forearms, abdominal wall, and face become swollen. The patient becomes anemic, and various skin eruptions appear. Pneumonia is likely to set in during this stage.

Fever usually occurs early in the disease during the first period, reaching its height about 10 days after the onset of the disease, and it persists or may show daily remissions throughout the second period. Fever is commonly absent in children. Death occurs most commonly from the fourth to the sixth week. It rarely occurs before the second week or after the seventh week.

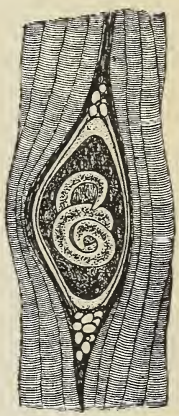


FIGURE 4.— Larvae of *Trichinella spiralis* encysted in a piece of muscle. Enlarged (after Leuckart).

It should be remembered that the symptoms outlined above are by no means constant and that in light cases the various stages of the disease are by no means clear. In many mild cases the symptoms may be so light as to pass by without any special notice. Even typical cases may be diagnosed as typhoid fever, and undoubtedly many cases, especially light cases, are never correctly or accurately diagnosed.

It has been shown that experimental trichinosis in rabbits may be diagnosed by a skin test and by a blood test. These tests, especially the skin test, have been used also in the diagnosis of trichinosis in man with good results.

Treatment

As a rule patients suffering from trichinosis are seen by a physician too late for the administration of an anthelmintic to remove the worms. There is no known medicinal treatment which will affect the embryos once their migrations have begun, and treatment at this and subsequent stages of the disease is entirely symptomatic. If patients are seen by a physician within a few hours or even a few days after ingesting trichinous pork and the disease is correctly diagnosed, some good may result from attempts to expel the worms from the intestines.

Prevalence of Trichinosis in Man

There is no comprehensive information on the prevalence of clinical trichinosis in human beings in the United States as this disease is not one that physicians are required to report to boards of health in all cases. Such figures as are available are based almost entirely on

records published by physicians in medical journals. Comparatively few physicians are in the habit of reporting their observations in medical journals, and cases of trichinosis are frequently confused with other febrile diseases, especially typhoid fever; light cases are probably seldom brought to the attention of a physician. Therefore statistical information on clinical trichinosis in the United States must be interpreted with considerable caution. The figures probably represent only part of the cases of this disease that have actually occurred.

Considering the main sources of infection with trichinae, namely, raw sausage, raw ham, and raw pork, it will be readily understood that infections with trichinae must be expected to be of relatively common occurrence among groups that are in the habit of consuming these products, especially at parties and family gatherings, where outbreaks of this disease often start.

The number of cases of trichinosis reported from the United States since 1842, when the parasite (*Trichinella spiralis*) was first discovered in human beings in this country, up to 1938 is approximately 6,000. States with large foreign populations, such as New York, Pennsylvania, Massachusetts, Minnesota, Illinois, and California, have a much higher percentage of cases than States having relatively small foreign populations. This is readily accounted for by the fact that the native population of this country is not in the habit of eating raw or rare pork, as a rule, whereas many European immigrants, notably Germans and Italians, have retained their native fondness for raw and imperfectly cooked pork and pork products.

In approximately 2,000 necropsies on human beings in which trichinae were actually looked for, about 2 percent of the bodies were found to harbor these parasites. In an additional series of about 500 necropsies in which trichinae were especially looked for, the percentage of infestation was slightly above 5. In another series of about 2,300 such examinations, carried out with far greater scientific precision than that used in the previous studies, the investigators reported an incidence of infestation as high as about 15 to 25 percent. From approximately 3,000 recent post-mortem examinations, in which trichinae were looked for especially, an incidence of 16.3 percent was reported. Most of the infected individuals examined contained few trichinae and were not known to have shown clinical symptoms during life. The incidence figures indicate that a fairly large proportion of the population probably acquire trichinae in numbers insufficient to produce recognizable clinical symptoms.

Prevention of Trichinosis

A rather wide prevalence of trichinae in American swine may be assumed from the knowledge that the parasites have world-wide distribution and are carried by rats, which wander extensively. Microscopic inspection of about 8,000,000 hogs, which was made in the United States between 1898 and 1906, when such inspection was compulsory for all hog carcasses intended for export, showed that between 1 and 2 percent of the animals were infested. Recent investigations carried out with thoroughness and precision have shown that the incidence of trichinae in garbage-fed hogs is on an average about 6 percent, whereas that in grain-fed hogs is slightly less than 1 percent.

It is essential, therefore, that consumers should take precaution to cook pork until it is well done, as thorough cooking destroys trichinae.

No practicable system of inspection has yet been devised by which persons who eat raw or imperfectly cooked pork can be protected from the danger of trichinosis. Certain European countries have an elaborate system of microscopic inspection of pork for trichinae. Experience has shown, however, that microscopic inspection is inherently imperfect and cannot be relied on as a completely effective preventive measure against trichinosis. It has been definitely shown that out of 6,329 cases of trichinosis which occurred in Germany between 1881 and 1898, 2,042 cases (over 32 percent) were caused by pork which had been inspected microscopically and passed as free from trichinae. While microscopic inspection would probably eliminate most of the heavily infested hog carcasses, many lightly infested carcasses would be overlooked, and the good that such inspection might accomplish would be largely offset by creating a false sense of security in the minds of persons who habitually eat raw or imperfectly cooked pork.

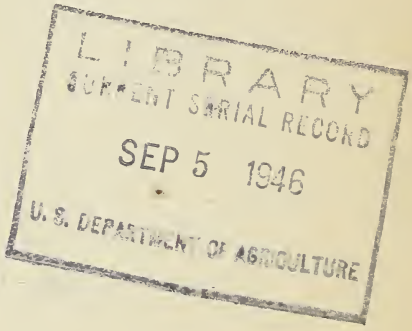
In the United States, in establishments operating under Federal supervision, pork products of kinds customarily eaten without cooking, such as Italian style ham, capocollo, and summer sausage, are especially processed to destroy trichinae and are safe for consumption without cooking by the consumer. These methods of processing, which involve cooking, refrigeration, or special curing, can be carried out effectively only in meat-packing establishments which are under the close scrutiny of a meat-inspection service. The methods other than cooking are not applicable to the preparation of pork products in the home and on the farm.

So far as concerns pork and pork products prepared at home and on the farm and pork and pork products purchased on the market and not designed to be eaten without cooking, the only safe rule is to cook thoroughly the pork and products containing muscle tissue. It should also be remembered in this connection that only about two-thirds of all animals slaughtered in this country are slaughtered under Federal inspection and that many plants operate without inspection or with only very inadequate inspection. Pork products of kinds customarily eaten without cooking, which are not wholly prepared in a meat-packing establishment that operates under Federal supervision, must be regarded as unsafe for consumption without cooking, unless one has first-hand assurance that competent inspection identical with that required by the regulations of the Bureau of Animal Industry of the United States Department of Agriculture is provided for locally.

During the winter season, particularly during the holidays, severe outbreaks of trichinosis are likely to occur. At that time of the year, smoked and dried sausage and various other products containing pork are eaten without cooking in households in which the eating of uncooked pork is customary. Such products, if they happen to have been made from hogs that were affected with trichinae, are some of the sources of trichinosis in this country. Entire families may be stricken, and numerous cases of trichinosis have resulted from the meat of one hog served as uncooked sausage, ham, or some similar product at a gathering or a family reunion, only those escaping who failed to eat the uncooked pork. Tasting sausage to ascertain when

the seasoning is satisfactory in preparing it is one method of acquiring trichinosis. Hamburgers also frequently contain some pork and, when not sufficiently cooked, may cause trichinosis. It should be remembered that large pieces of pork require much more cooking than small ones because heat penetrates slowly into meat in the process of cooking, and that large pieces that are well cooked on the outside may be imperfectly cooked or almost entirely raw in the center. In a series of 24 cases of trichinosis reported recently, 22 were said to have resulted from "cooked pork." Evidently a considerable number of persons do not cook pork sufficiently to destroy trichinae. Care should therefore be taken that pork is "done" throughout and not merely in the outer portions.

The prevention of trichinosis is a personal responsibility, at least in part, and involves the thorough cooking of all pork. Pork products of kinds customarily eaten without cooking are also dangerous unless it is definitely known that such products were prepared in a plant operating under Federal meat inspection or equally thorough State or local supervision.



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